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The effect of cover crop and straw applied for manuring on spring barley yield and agrochemical soil properties

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Abstract

Research was carried out during the period 2003–2006 at the Joniškėlis Experimental Station of the Lithuanian Institute of Agriculture on a clay loam *Gleyic Cambisol* (*CMg*). It was designed to ascertain the effect of cover crop biomass (*Trifolium pratense* L., *Trifolium repens* L., *Lolium multiflorum* Lamk., *Sinapis alba* L.) and straw, applied for manuring, on the yield of crops and agrochemical soil properties. It was estimated that the accumulated total energy content in the yield of spring barley during the two years of effect had been significantly increased by cover crop and its interaction with straw. The moderate rates of mineral fertilizers (N – 140, P – 26.2, K – 49.8 kg ha^{-1}) in most cases determined the negative balance of nutrients. A cover crop, used for manuring, alone or together with straw, did not always ensure nitrogen content, necessary for mineralization of straw as well as NPK nutrition of spring barley. Most of the positive effects on the variation of mobile potassium in the soil resulted from the application of straw for manuring. The trends of total nitrogen increase were identified after straw with mineral nitrogen fertilizer or cover crop biomass had been used for manuring.

Key words: cover crop, straw, cereal yield, NPK yield, agrochemical soil properties.

Introduction

Optimal potential of soil fertility is mainly defined by agrochemical properties: pH neutral, average or major contents of mobile phosphorus, potassium and humus. The higher rate of accumulation and spread of nutrients and organic matter in the soil as well as humidity, air, temperature regimes are defined by the soil texture too: sandy loam and clay loam (Teit, 1991). These properties are characteristic of the majority of soils in Central Lithuania’s region, which influence successful development of agricultural production. Though, under the influence of market conditions, specialization of farms is narrowing – the number of livestock and mixed farms is declining, the amount of legume crops is low, 2–3 most profitable crop species dominate. Good preceding crops are covered by increased rates of mineral fertilizers, pesticides, intensive species of crops, reduction of soil tillage to minimal etc. However, after Lithuania had joined the European Union, requirements for environment protection increased and agricultural producers are obliged to maintain and increase the soil productivity. It can be attained by using rational rates of mineral fertilizers, increasing the amount of organic fertilizers and applying technological aids to minimize the negative impact on environment (Aronson et al., 2007).

In order to maintain soil fertility, the main role is given to the ratio of fertilizer rate to yield. Reserves of phosphorus and potassium in the soil without fertilizer application can secure a crop yield of approximately 1.9–2.1 t ha^{-1} (Švedas, 1990). Higher yields condition negative balance of nutrients and reduction of soil fertility. In clay loam *Gleyic Cambisol*, without using fertilizers, the potassium content was reduced by 5.3% and that of phosphorus by 41.8% during the five-crop rotation (Bagdonienė, Arlauskienė, 1999). The highest yield was produced after fertilization with maximum rates of nitrogen, phosphorus and potassium fertilizers (Singh, Dalai, 2006). However, the yield differences were slightly lower compared to optimal rates of fertilizers. Moreover, if fertilized with lower rates, the efficiency of fertilizer is growing, therefore the pollution is lower. Yield of crops is mostly increased by mineral nitrogen fertilizers (39.1%) compared to phosphorus or potassium (9.9 and 5.3% respectively) (Mažvila et al., 2007). Furthermore, they significantly influence the quality of yield of cereals. Considering the needs of crops and due to the influence of meteorological conditions, rates of nitrogen fertilizer are often increased. Researchers have indicated that the efficiency of nitrogen fertilizer declined by 30–46% during the year of normal humidity and by 35–62% during the dry year (Janušauskaitė, Šidlauskas, 2004). Nutrition of crops involves different elements; therefore nitrogen fertilizers are to be used in appropriate ratio with phosphorus and potassium fertilizers. Petraitiene reported that in the case of long term (15 years) fertilization with nitrogen fertilizers only, mobile phosphorus content was reduced 55–110 mg kg^{-1}, mobile potassium – 71–88 mg kg^{-1} of soil (Petraitienė, 2000). Mineral nitrogen content in the soil as well as its leaching into the ground water significantly increases in the autumn because of plentiful fertilization with nitrogen fertilizers (Arlauskienė, Maikštėnienė, 2008; Mažvila et al., 2009). Scientists suggest not using higher rates of mineral fertilizers than $N_{120}P_{120}K_{120}$ in order to protect the environment (Mažvila et al., 2007). The findings of many researchers indicate that fertilizers and soil are utilized in the most rational way when moderate fertilizer rates are adjusted according to agrochemical soil properties and in respect with nutrient balance (Pekarskas et al., 2008; Mažvila et al., 2009).

Other technological aids are important too in order to optimize fertilizer rates. Nutrient elements (P and K) accumulate more in the topsoil when applying ploughless soil tillage and this determines higher yield surplus in the soil relatively poor in fertilizer-nutrients compared to conventional soil tillage (Feiziene, 2008).

Many fertilization experiments have been carried out in rotations of a variety of crops, where fertilization was dependant upon a preceding crop. Roots of preceding crops and residues, left in the soil, are the important source of nutrients for succeeding rotation crops (Watson et al., 2002). Research evidenced that the soil receives the majority of NPK nutrients with residues of mixture of red clover and grass respectively 132.1, 38.0, 61.3 kg ha^{-1}, with lucerne 209.8, 69.7, 90.2 kg ha^{-1}. Meanwhile the soil receives considerably less with the residues of cereals: nitrogen 4.4 times, phosphorus 5.0 times and potassium 3.6 times (Magyla et al., 1994). Therefore they are identified as crops, exhausting the soil. With an expansion of area of cereals in the rotation by more than 50% the amount of crop residues as well as input of nutrients into the soil reduce. The release of nutrients from residues depends on their quality – ratio of C:N (Watson et al., 2002; Velička et al., 2006). Accordingly, the interchange of crops with different quality of roots and residues ensures synchronic mineralization of organic matters as well as nutrient supply for succeeding crops (Singh, Dalai, 2006).

Crops differ by biological and morphological properties, biomass and chemical composition as well as by influence on the soil fertility. Legume crops are valued due to enrichment of soil with symbiotic nitrogen from the atmosphere. Researchers indicated that plants with roots reaching deep into the subsoil (fodder radish, white mustard) can utilize nutrients from deeper soil surface layers and stop their leaching (Thorup-Kristensen, 2010). Moreover, root secretion of some plants is able to decompose some compounds of phosphorus and potassium inaccessible for plants and form accessible ones. Research, performed in Germany, revealed that white mustard assimilates phosphorus irrespective of the form of phosphates in the soil (Постников и др., 2001). Other authors indicate that compositions, badly accessible for plants in the soil are dissolved by acids from roots of lupin, serradella, buckwheat (Freyer, 2003). The majority of plants assimilate phosphorus from soil with the help of arbuscular mycorrhizal fungi.

The objective of the study is to identify the effect of cover crops' (red clover, white mustard and mixture of white clover with Italian ryegrass) biomass and straw, applied for manuring on the yield and agrochemical soil properties.

Materials and methods

Two bi-factor field trials (1st and 2nd experiment) were carried out during the periods 2003–2005 and 2004–2006 at the Joniškėlis Experimental Station of the Lithuanian Institute of Agriculture. Research was done in the northern part of Central Lithuania's lowland. The soil characteristic of the larger part of this region is *Endocalcari-Endohypogleyic Cambisol* (*CMg-n-w-can*). The arable soil layer is moderate in phosphorus (P_2O_5 123–125 mg kg^{-1} soil), high in potassium (K_2O 216–229 mg kg^{-1} soil) and moderate in humus (organic carbon 1.28–1.38%).The soil texture is clay loam on silty clay with deeper lying sandy loam.

Experiments involved the following design: *factor A* – utilization of winter wheat straw: 1) straw removed from the field, 2) straw chopped and spread; *factor B* – cover crops: 1) without cover crops, stubble not broken (check – A background, treatment 1), 2) without cover crop, stubble broken,

3) red clover (*Trifolium pratense* L.), 4) white clover (*Trifolium repens* L.) and Italian ryegrass (*Lolium multiflorum* Lamk.) mixture, 5) white mustard (*Sinapis alba* L.).

Cover crops were grown in the same year as winter wheat (*Triticum aestivum* L.), with no separate field allocated. Cover crops: undersown red clover, white clover mixture with Italian ryegrass (seed rate ratio 1:1) and post-crop white mustard. Cover crops were undersown into winter wheat early in spring when the soil had dried sufficiently. Post-crops were sown shortly after wheat harvesting (on the same day), the straw was either removed (factor A, treatment 1) or chopped and spread (factor A, treatment 2). Post-sowing, ammonium nitrate (N_{45}) was applied for optimal growth of white mustard (on both straw backgrounds, treatment 5) and straw (5 t ha^{-1}) (factor A, treatment 2) mineralization. In the middle of October the biomass of cover crops was chopped and incorporated into the soil. The effects of the measures used were monitored for two years by growing spring barley (*Hordeum vulgare* L.) employing conventional soil and crop management practices.

Before incorporating into the soil, the amount of cover crops' above-ground biomass was weighed, and stubble of 5–7 cm height was left. Samples were taken for the determination of dry matter (dried to a constant weight at 105°C), nitrogen, phosphorus and potassium. The above – ground biomass of all plants was recalculated into dry matter and nitrogen, phosphorus and potassium accumulation was calculated. Nitrogen in plant samples was determined by the Kjeldahl (ISO 20483: 2006), phosphorus – spectrophotometric methods, potassium – flame photometer. The total energy (TE) of spring barley was re-calculated according to the amount of grain yield (DM) multiplying it by 18.48, straw – by 17.92 (Jankauskas, Jankauskienė, 2000).

Soil samples for the determination of mobile phosphorus and potassium and total nitrogen content were collected from 0–25 cm layer before trial establishment and in the second year of effect of cover crops' biomass and straw incorporation after spring barley harvesting. Available P_2O_5 and K_2O in the soil were determined by ammonium lactate extraction Egner-Riem-Domingo (A-L) (GOST 26208-91:1993), total nitrogen – by Kjeldahl (ISO 11261:1995) methods.

The mean daily air temperature and precipitation during the experimental period were similar to the long-term mean. The experimental data were processed by the analysis of variance and correlation-regression analysis methods using a software package *Selekcija* (Tarakanovas, Raudonius, 2003).

Results and discussion

Cover crops. Effect of cover crops in agro-system was estimated considering their yield and accumulated nutrient content. Under favourable meteorological conditions, cover crops can accumulate from 3.34 to 5.78 t ha^{-1} dry matter (DM) (1st experiment, 2003), under less favourable – 1.25–3.75 t ha^{-1} DM (2nd experiment, 2004). Undersown cover crops – red clover, mixture of white clover and Italian ryegrass – produced the highest biomass during all years of study. Biomass of post-crop white mustard and accumulation of nutrients were mainly dependent upon precipitation rate after wheat harvesting. Moreover, their initial growth required nitrogen fertilizer (N_{45}). Cover crops mainly accumulated nitrogen and potassium, less – phosphorus (Table 1). Legumes enriched the soil with symbiotic nitrogen (N_2). Red clover accumulated on average 79.7 kg ha^{-1} of atmospheric nitrogen (N_2) in the biomass. The major content of potassium was restored in the soil with straw as well as small amount of nitrogen and phosphorus. The rate of soil-incorporated winter wheat straw during the first experiment was 6.30 t ha^{-1} DM, during the second – 5.37 t ha^{-1} DM.

Table 1. Nitrogen, phosphorus and potassium content accumulated in the biomass of cover crops and straw
Joniškėlis Experimental Station

Cover crops	1st experiment, 2003			2nd experiment, 2004			Average		
	nutrient content kg ha^{-1}								
	N	P	K	N	P	K	N	P	K
RC	149.4	16.1	134.2	89.8	10.3	74.7	119.6	13.2	104.5
WC + IR	94.3	14.2	104.6	76.8	9.8	89.4	85.6	12.0	97.0
WM	113.5	15.8	162.2	38.7	4.9	41.8	76.1	10.3	102.0
LSD_{05}	12.57	1.83	18.92	14.24	1.57	11.58	14.58	2.40	28.60
Straw	20.7	2.6	76.2	31.2	3.9	74.2	26.0	3.3	75.2

Note. RC – red clover, WC + IR – mixture of white clover and Italian ryegrass, WM – white mustard (+N_{45}).

Total energy. After incorporation of cover crop biomass with straw for manuring different total energy content was accumulated in the yield of spring barley, cultivated for two years (Table 2). The first experiment indicated that the significant effect on the accumulation of total energy in the first year yield of spring barley was made by cover crop ($F_{fact.}$ = 4.21**, LSD_{05} = 8.35) as well as interaction with straw ($F_{fact.}$ = 5.08**, LSD_{05} = 11.81). The highest positive effect was exerted by incorporation of red clover (alone or with straw) and white mustard (N_{45}) biomass; increase in yield was 15.6, 10.6 and 12.0% respectively, compared to the check treatment. Straw, used with mineral nitrogen fertilizers (N_{45}, with stubble broken or stubble not-broken) or cover crop biomass (except white mustard) increased the total energy content too. During the second year of study, the effect of straw and cover crop was not significant. Straw (N_{45}), used for manuring, increased the total energy content by on average 4.5% in the yield of spring barley (grain and straw). The highest total energy content in the yield was accumulated when straw (N_{45}) had been used for manuring and with stubble breaking; the yield increase was 10.1%, compared to the check treatment.

Table 2. The effect of cover crops and straw on the accumulation of total energy (GJ ha^{-1}) in spring barely yield (grain and straw)

Joniškėlis Experimental Station

Cover crops (B)	1st experiment, 2004–2005			2nd experiment, 2005–2006		
	first year	second year	sum	first year	second year	sum
Straw use (A) – removed from the field						
Without cover crop	150.4	102.2	252.6	108.5	109.3	217.8
Without cover crop, stubble broken	154.2	104.6	258.8	106.9	101.3	208.2
RC	173.9	105.8	279.7	111.4	113.2	224.5
WC + IR	150.5	105.6	256.1	100.2	111.3	211.6
WM	168.5	102.7	271.2	111.2	116.7	228.0
Means for factor A	159.5	104.2	263.7	170.6	110.4	218.0
Straw use (A) – chopped and spread						
Without cover crop	162.1	109.5	271.6	113.7	112.8	226.5
Without cover crop, stubble broken	162.2	112.5	274.7	108.3	112.5	220.7
RC	166.4	108.9	275.3	107.8	110.6	218.4
WC + IR	160.9	107.5	268.4	93.0	104.5	197.6
WM	150.8	106.0	256.8	103.8	111.3	215.1
Means for factor A	160.5	108.9	269.4	105.3	110.3	215.6
LSD_{05} A	5.28	4.69	6.79	4.83	3.22	4.95
LSD_{05} B	8.35	7.41	10.74	7.64	5.09	7.83
LSD_{05} AB	11.81	10.49	15.19	10.81	7.19	11.07

Note. Explanation under Table 1.

The highest productivity of spring barley during the period of the 1st experiment (2004–2005) was observed when red clover biomass was used for manuring alone or together with straw; the total energy content was higher by 10.7 and 9.0% respectively, compared to the check treatment. Straw (N_{45}), with stubble broken or stubble not-broken, used for manuring also significantly increased the total energy content (8.7, 7.5% respectively). The least productivity of spring barley was observed after incorporation of white mustard biomass together with straw (N_{45}) for manuring or mixture of white clover with Italian ryegrass biomass alone.

The findings of the 2nd experiment revealed that the total energy content in the yield was by 18.6% lower compared to averaged data of the 1st experiment. The effect of the measures applied was less important. During the first year of effect of the measures applied, the total energy content significantly depended on cover crops ($F_{fact.}$ = 4.68*, LSD_{05} = 7.64). The effect of straw was not significant. White mustard biomass (N_{45}), straw ($N_{45,}$ stubble not-broken), red clover biomass tended to increase total energy content compared to the check treatment. However, compared to similar data when straw had been removed from the field, only straw (N_{45}) with stubble broken or stubble not-broken, increased (by 1.2 and 4.8% respectively) total energy. Significantly lower total energy content was accumulated in the yield of spring barley, grown after incorporation of biomass of mixture of white clover and Italian ryegrass as well as straw.

Similar data were obtained in the second year of study. Significant effect on the total energy content was exerted by a cover crop ($F_{fact.}$ = 2.79*, LSD_{05} = 5.09) and especially – interaction of straw and cover crop ($F_{fact.}$ = 4.47**, LSD_{05} = 7.19).

During the period of the 2nd experiment (2005–2006) the total energy content was significantly influenced by cover crops ($F_{fact.}$ = 7.82**, LSD_{05} = 7.83) and their interaction with straw ($F_{fact.}$ = 5.20**, LSD_{05} = 11.07). The highest total energy content in the yield was identified where mineral nitrogen fertilizer (N_{45}) had been applied for mineralization of straw or for growth of white mustard. Higher spring barley productivity (by 4.7%) compared to the check treatment, was recorded where white mustard biomass was applied for manuring. In the cases when straw (N_{45}, with stubble broken or stubble not-broken) and biomass of red clover were applied for manuring, the total energy content increased. During two years of the 2nd experiment the lowest total energy content was accumulated in the yield of spring barley when mixture of white clover and Italian ryegrass biomass together with straw was applied for manuring.

Literature sources suggest that one of the main indicators, determining the mineralization rate of incorporated organic matter and yield for the succeeding year is appropriate ratio of incorporated organic carbon and nitrogen (C:N). Significant role here is given to nitrogen, determined by the type of crops and nitrogen concentration in biomass (Jensen et al., 2005). C:N ratio is declining with increasing nitrogen; therefore intensity of microbiological processes (C_{mic}) or decomposition of incorporated organic matter increases (Ding et al., 2006; Lejon et al., 2007). The findings from the 1st experiment evidenced that red clover and white mustard biomass initiated rapid mineralization and increased the crop yield for the succeeding year. Researchers from different countries have reported that using straw fertilization with the addition of mineral nitrogen fertilizer, nitrogen immobilization stage can be prolonged and the yield of main crops reduced in succeeding year (Malecka, Blecharczyk, 2008; Lafond et al., 2009). During our studies, nitrogen, immobilized in microorganism biomass in autumn, initiated release in the second half of summer of the succeeding year, therefore the yield of spring barley of first and second year of effect increased. Other researchers obtained similar results (Mayer et al., 2003).

The data of the 2nd experiment suggest that mixture of white clover and Italian ryegrass biomass was characterized by higher C:N ratio, lignin content and slow degradation (Arlauskienė, Maikštėnienė, 2008). Similar processes were observed in the soil after straw incorporation together with cover crop biomass; therefore spring barley yield during the first year declined. Other researches indicate similar findings (Malecka, Blecharczyk, 2008). The yield during the second year was not characterized more distinctly. Such processes of incorporated organic matter transformation in the soil could be determined by biomass quality as well as by the lack of humidity, high temperature fluctuation rate in autumn which causes weak microbiological processes and transfer to the period of spring-summer of the succeeding year.

N, P, K yield. The data of the effect of cover crop and straw, used for manuring, on the accumulation of nitrogen, phosphorus and potassium in the yield of crops (grain and straw), cultivated in the period of two years are presented in Table 3.

The data of the 1st experiment (2004–2005) suggest that mineral nitrogen fertilizers (140 kg ha^{-1} N) were used for the main fertilization of spring barley, and compensated nitrogen content output by 79.4–92.3%. In all cases the nitrogen balance was negative from −11.7 to −36.3 kg ha^{-1}. Nitrogen concentration in spring barley grain yield during the first year was lower (15.4–17.9 g kg^{-1} DM) than that during the second year (17.3–20.7 g kg^{-1} DM). Nitrogen content, accumulated in cereal yield significantly depended on the means of straw application ($F_{fact.}$ = 7.22*, LSD_{05} = 3.84) and cover crop types ($F_{fact.}$ = 8.04**, LSD_{05} = 7.19). The interaction between the two factors was not significant. Significantly higher nitrogen content (15.9%) was identified in spring barley grain and straw, accumulated after biomass of red clover had been applied for green manure compared to the check treatment. Moreover, nitrogen accumulation in the yield of cereal was significantly increased (8.2–15.6%) by the application of straw together with the addition of nitrogen fertilizer (N_{45}, with stubble broken or stubble not-broken) or legume cover crop biomass (red clover and mixture of white clover with Italian ryegrass).

Phosphorus content in spring barley yield during the two-year period of cultivation was low, compared to that of nitrogen and potassium. After application of 60 kg ha^{-1} P_2O_5 for spring barley every year (26.2 kg ha^{-1} P in two years), phosphorus content output in crop yield was compensated 74.9–83.7%. Balance of phosphorus varied from −5.1 to −8.8 kg ha^{-1}. Phosphorus was mainly accumulated in grain. Accumulation of phosphorus in spring barley yield was significantly dependent upon cover crop ($F_{fact.} = 3.22$*, $LSD_{05} = 1.53$) and interaction between application of straw and cover crop ($F_{fact.} = 3.21$**, $LSD_{05} = 2.16$). During the two-year period of spring barley cultivation, significantly higher phosphorus content was accumulated if red clover biomass was applied as manure, i.e. 8.7% higher compared to the check treatment. Application of cover crop of other type and straw did not have any major influence on the accumulation of phosphorus in the yield.

Table 3. The effect of cover crops and straw on the accumulation of nitrogen, phosphorus and potassium in the spring barely yield (grain and straw)

Joniškėlis Experimental Station

Cover crops (B)	1st experiment, 2004–2005			2nd experiment, 2005–2006		
	N	P	K	N	P	K
	kg ha^{-1}					
Straw use (A) – removed from the field						
Without cover crop	152.1	32.2	81.6	171.9	24.6	74.6
Without cover crop, stubble broken	151.7	31.3	81.4	167.6	23.6	66.8
RC	176.3	35.0	83.7	174.0	25.7	74.6
WC + IR	154.6	31.5	79.6	167.7	24.6	71.9
WM	153.5	33.8	96.8	189.4	26.0	77.6
Means for factor A	157.6	32.8	84.6	174.1	24.9	73.1
Straw use (A) – chopped and spread						
Without cover crop	166.2	33.7	90.5	183.7	25.2	74.3
Without cover crop, stubble broken	164.6	33.8	94.7	184.3	25.1	74.7
RC	175.9	33.5	95.0	171.8	24.8	66.5
WC + IR	165.0	32.3	91.3	157.7	24.4	61.3
WM	157.0	32.0	86.5	169.4	24.1	66.3
Means for factor A	165.7	33.1	91.6	173.4	24.7	68.6
LSD_{05} A	3.84	0.82	2.14	3.31	0.56	1.47
LSD_{05} B	7.19	1.53	4.00	6.20	1.05	2.74
LSD_{05} AB	10.17	2.16	5.65	8.76	1.48	3.88

Note. Explanation under Table 1.

Potassium concentration in spring barley grain was lower (the first year – 4.36–5.30 g kg^{-1} DM, the second – 3.70–4.22 g kg^{-1} DM) than nitrogen concentration, but higher than that of phosphorus. Potassium accumulation in the yield from all nutrients by potassium fertilizers (49.8 kg ha^{-1}) was compensated the least – 51.4–62.6%. Therefore the highest negative potassium balance (from −29.8 to −47.0 kg ha^{-1}) was identified. Unlike nitrogen and phosphorus, potassium in spring barley was mostly accumulated in straw (on average 53.6 kg ha^{-1}), while in grain – on average 33.9 kg ha^{-1}. Accumulated potassium content (2004, 2005) in the yield of spring barley was significantly different if straw ($F_{fact.}$ = 17.87**, LSD_{05} = 4.00), cover crop of different types were applied for green manure ($F_{fact.}$ = 2.69*, LSD_{05} = 4.00) as well as in interaction of both factors ($F_{fact.}$ = 11.52*, LSD_{05} = 5.65). Research data indicated that the major potassium content had been accumulated after incorporation of white mustard biomass (N_{45}) 96.8 kg ha^{-1} or 18.6% more compared to the check treatment. Other fertilizers applied also increased potassium accumulation in spring barley yield: straw (N_{45}, with stubble broken or stubble not-broken) 16.1 and 10.9% respectively, straw together with red clover biomass – 16.4%, straw with mixture of white clover and Italian ryegrass biomass – 11.9%, compared to the check treatment (all mentioned changes were significant).

The data from the 2nd experiment (2005–2006) suggest that nitrogen content, accumulated in the yield was higher by 7.4%, phosphorus content was lower by 24.6% and potassium content was lower by 19.5% compared to the data of the 1st experiment. Nitrogen output with the yield was compensated 73.9–88.8% by mineral nitrogen fertilizers (140 kg ha^{-1} N). Nitrogen balance was negative – from −17.7 to −49.4 kg ha^{-1}. Nitrogen concentration in spring barley grain was higher during the first year (from 20.6 to 23.2 g kg^{-1} DM), and the second (from 22.6 to 24.9 g kg^{-1} DM) compared to the first experiment. Nitrogen accumulation in cereal was significantly influenced by application of cover crop ($F_{fact.}$ = 6.72**, LSD_{05} = 6.20). Compared to the 1st experiment, the influence of straw was weak, but the effect of interaction of both factors – significant ($F_{fact.}$ = 9.10**, LSD_{05} = 8.76). Compared to the check treatment, the highest amount of nitrogen (during the period of two years), was accumulated in spring barley yield when white mustard biomass (N_{45}), straw (N_{45}, with stubble broken or stubble not-broken) were used for manure. The differences were significant (10.2, 7.2 and 6.9% respectively). The lowest nitrogen content was accumulated in the yield when straw together with mixture of white clover and Italian ryegrass biomass, were applied for manure – 14.2 kg ha^{-1} or 8.3% less compared to the check treatment.

Phosphorus content in the yield varied little, compensation with mineral phosphorus fertilizers (incorporated 26.2 kg ha^{-1} P) was 100.8–110.0%, and the balance was positive low (+0.2–+2.6 kg ha^{-1}). Significant effect on phosphorus accumulation in the yield was exerted by both factors: interaction between application of straw and cover crop ($F_{fact.}$ = 2.43*, LSD_{05} = 1.48). Researchers state, that the balanced application of phosphorus fertilizers on crops with a low positive phosphorus balance in agro-ecosystem influenced the higher yield as well as limited the process of phosphorus compounds' leaching by drainage (Thorup-Kristensen, 2010).

Lower potassium accumulation in spring barley yield cultivated in the period of two years (2005 and 2006) was influenced by lower grain yield and lower potassium concentration in grain (in the first year – 3.88–4.25 g kg^{-1} DM, the second – 2.55–3.12 g kg^{-1} DM) compared to the 1st experiment. Mineral fertilizers (49.8 kg ha^{-1} K) compensated potassium accumulation in yield 64.2–81.2%, the balance was negative (from −11.5 to −27.8 kg ha^{-1}). Like in the first experiment, significant influence on potassium accumulation in the yield of cereal was exerted by application of straw ($F_{fact.}$ = 36.00**, LSD_{05} = 1.47), cover crop ($F_{fact.}$ = 10.23**, LSD_{05} = 2.74) and interaction of those factors ($F_{fact.}$ = 12.14**, LSD_{05} = 3.88). Average data suggest that potassium content, higher by 6.6% was accumulated in crop yield with straw removed from the field compared to straw used for manure. The lowest potassium content was accumulated in cereal yield with stubble broken and application of straw together with cover crop biomass for manure. Potassium content in the yield was reduced the most when straw had been incorporated with mixture of white clover and Italian ryegrass biomass (17.8%); decrease was observed after incorporation of white mustard (N_{45}) (11.1%) and red clover (10.9%) biomass; differences, compared to check treatment, were significant.

Influence of cover crop biomass and straw, used for manure on accumulation of nutrients in spring barley yield, cultivated for the period of two years, was dependent upon the quality of incorporated organic matter, decomposition time and rate. The major role is given to nitrogen, which was incorporated with cover crop biomass or mineral nitrogen fertilizers. The data of the 1st experiment indicate that nitrogen rich red clover and white mustard (N_{45}) biomass (positive C:N ratio), performed more rapid mineralization, increased the amount of mobile humic acids and improved spring barley nutrition with nitrogen and other elements; the mentioned above was indicated by other researchers too (Jensen et al., 2005). Straw, incorporated with nitrogen fertilizers and cover crop biomass ensured better nutrition of spring barley by main NPK elements. During the year, less favourable for cover crop cultivation (2nd experiment), the influence of cover crop was lower and the higher effect was exerted by mineral nitrogen fertilizers. The majority of surveys indicate that it is important that a balance between inputs and outputs of nutrients is achieved to ensure both short-term productivity and long-term sustainability (Stockdale, Watson, 2002).

Total nitrogen. The variation of total nitrogen in the soil prior to the experiment establishment and after two years, which occurred due to the application of cover crop and straw for manuring, is presented in Table 4. The data of the first experiment indicate that when straw was removed from soil, total nitrogen content in the soil reduced by 4.5%, and when straw was used for manure – reduced by 2.6%, compared to the data prior to experiment establishment. Where straw was removed from the field, the highest amount of total nitrogen was identified after red clover or biomass of white clover mixture with Italian ryegrass were used for the green manure, 7.5 and 6.8% respectively, compared to the check treatment. All ways of straw application for fertilizing (together with nitrogen fertilizers or cover crop biomass) as well as cover crop biomass increased (1.4–8.8%) total nitrogen content in soil, except for the cases, when straw was incorporated by a stubble breaker.

Table 4. The effect of cover crops and straw on total nitrogen, mobile phosphorus and potassium concentration in the soil

Joniškėlis Experimental Station

Cover crops (B)	1st experiment, 2004–2005			2nd experiment, 2005–2006		
	N_{total}	mobile P_2O_5	mobile K_2O	N_{total}	mobile P_2O_5	mobile K_2O
	mg kg^{-1} of soil					
Before experiment establishment	1.56	123	216	1.35	125	229
Straw use (A) – removed from the field						
Without cover crop	1.47	121	240	1.32	133	243
Without cover crop, stubble broken	1.39	119	239	1.29	129	240
RC	1.58	109	226	1.25	137	239
WC + IR	1.57	104	232	1.24	126	246
WM	1.46	106	238	1.42	129	247
Means for factor A	1.49	112	235	1.30	131	243
Straw use (A) – chopped and spread						
Without cover crop	1.60	118	251	1.34	136	264
Without cover crop, stubble broken	1.43	117	255	1.40	139	258
RC	1.49	113	252	1.41	139	263
WC + IR	1.53	118	256	1.38	139	260
WM	1.57	117	252	1.39	141	264
Means for factor A	1.52	117	253	1.38	139	262
LSD_{05} A		6.9	5.1		14.6	6.3
LSD_{05} B		12.9	9.6		27.3	11.9
LSD_{05} AB		18.2	13.5		38.6	16.8

Note. Explanation under Table 1.

Total nitrogen content in the soil during the second experiment was changing differently, due to applied means. Where straw was removed from the field, total nitrogen reduced by approximately 3.7%, meanwhile when straw was used for fertilizing together with mineral nitrogen fertilizer (N_{45}) or cover crop biomass, it increased by on average 2.2%, compared to the data before experiment establishment. When straw was removed from the field, total nitrogen content was reduced by biomass of all cover crop, except white mustard (N_{45}). Meanwhile straw, used together with mineral nitrogen fertilizer (N_{45}) or cover crop biomass, increased total nitrogen content in soil by 1.5–6.8%, compared to the check treatment.

The data averaged over the two experiments revealed that cover crop, i.e. red clover, biomass of white clover mixture with Italian ryegrass and white mustard did not have any significant effect on change of total nitrogen content in the soil in two years after their application as green manure. More significant increase of total nitrogen was identified after straw with mineral nitrogen fertilizer or cover crop biomass had been used for fertilizing. These organic matters, due to optimal carbon to nitrogen ratio, ensured appropriate nutrition of crops by nitrogen, as well as positive balance of humus and total nitrogen (Ding et al., 2006). These processes differ between years in short-term research. They depend on soil humidity, micro-organism distribution and activity (Aronsson et al., 2007). Research carried out in Russia indicates that application of cover crop and straw together with mineral fertilizers in a rotation for a long period of time, increased soil humus content by 16.9%, nitrogen by 11.0%, compared to mineral fertilizers only (Лошаков и др., 1998).

Mobile P_2O_5. The data on the change of mobile phosphorus in the topsoil (0–25 cm) prior to the experiment establishment and two years after incorporation of cover crop biomass and straw are presented in Table 4. Soil phosphorus data (P_2O_5) were dependent upon the amount of applied mineral fertilizer and productivity of crop rotation.

The data of the first experiment indicate that mobile phosphorus content, compared to that before trial establishment, was reduced by 8.9%, after straw was removed from soil and if straw was used for manure by 4.9%. Significant influence on phosphorus content in the soil was exerted by application of straw only ($F_{fact.} = 4.49^*$, $LSD_{05} = 6.9$). Application of cover crop biomass only for green manure led to the tendency of phosphorus content reduction in the soil (9.9–14.0%), compared to the check treatment. Moreover, application of crops' biomass together with cereal straw reduced this difference to 2.5–6.6%.

During the second experiment, two years after cultivation of cereals, mobile phosphorus content in the soil increased (on average by 8.0%), unlike in the first experiment, compared to the data before experiment establishment. This was determined by lower spring barley yield and accumulated total energy content in it. The difference was on average 49.7 GJ ha^{-1} or 18.6% lower compared to the data of the first experiment. The findings of the second experiment suggest that the influence of cover crop and straw on mobile phosphorus content in the soil was not substantial with cultivation of spring barley for two years. Positive effect on mobile phosphorus accumulation was exerted by application of straw together with nitrogen fertilizer (N_{45}) or cover crop biomass for fertilizing. Mobile phosphorus content in the soil in the treatments, mentioned above, was 2.2–4.5 and 4.5–6.0% respectively higher compared to the check treatment.

Averaged data of the two experiments show that the influence of applied measures on mobile phosphorus content in the soil was not significant. This can be explained by the fact, that the green crops' mass increased the yield as well as accumulation of phosphorus in it. Moreover, cover crops in biomass accumulated and restored relatively small amount of phosphorus in the soil. Long-term (30 years) studies, performed in Germany indicate that in various agricultural systems, the highest negative phosphorus balance was identified in conventional and stockless agricultural systems (Лошаков и др., 1998).

Mobile K_2O. Research, carried out in 2005 (1st experiment) on a clay loam *Gleyic Cambisol* (with high potassium content), two years after cultivation of spring barley, indicated, that mobile potassium content increased by on average 13.0%, compared to the data before trial establishment. The data of the first experiment suggest that accumulation of mobile potassium in the soil was influenced by the application of straw for manure ($F_{fact.} = 63.17^{**}$, $LSD_{05} = 5.1$). Cover crop, used for the green manure, fractionally reduced mobile potassium content in soil (0.8–5.8%) compared to the check treatment (Table 4). Meanwhile straw, applied for fertilization together with mineral nitrogen fertilizers (N_{45}) or cover crop biomass, increased its content (by on average 7.7%), compared to the cases when straw was removed from the field. Significantly higher mobile potassium content was identified in the soil when straw (N_{45}) was applied for manure (incorporated by a stubble breaker) or in combination with biomass of white clover mixture with Italian ryegrass. Mobile potassium content in the cases, mentioned above, increased by 6.3 and 6.7% respectively, compared to the check treatment.

The data of the second experiment (2006) indicate that mobile potassium content was mainly influenced by application of straw for manure ($F_{fact.} = 35.04^{**}$, $LSD_{05} = 6.4$). Mobile potassium content, compared to the data before trial establishment, increased by on average 10.3%. The property of cover crop to bind large mobile potassium content, available for crops during the period after cereal harvesting did not reveal any significant influence on the changes of potassium content in soil. Meanwhile straw, applied for manure (N_{45}), increased mobile potassium amount in the soil by 6.2–8.6%, and straw, applied together with cover crop biomass – 7.0–8.6%, compared to the check treatment.

Averaged data of both experiments indicated that changes of mobile potassium content in the soil, containing high levels of potassium, were significantly positively influenced by the return of straw to the soil. Cover crop influenced spring barley yield more and did not have any essential influence on the soil.

Conclusions

1. Total energy content in the yield of spring barley, cultivated during the period of two years, was mainly increased by incorporated cover crop of red clover (*Trifolium pratense* L.) and white mustard (*Sinapis alba* L.) biomass (N_{45}), on average by 7.2 and 6.1% respectively, compared to that in the field without cover crop. Straw (N_{45}), applied for manure, with stubble broken or stubble not-broken, increased total energy content in cereal yield, on average by 5.9 and 5.3%. Application of straw for manure together with biomass of various cover crops was one-to-many: red clover increased total energy content, while mixture of white clover (*Trifolium repens* L.) and Italian ryegrass (*Lolium multiflorum* Lamk.) reduced.

3. The applied moderate fertilizer rates of mineral nitrogen, phosphorus and potassium fertilizers (N – 140, P – 26.2, K – 49.8 kg ha^{-1} respectively) in most cases determined negative nutrient balance and compensation coefficients of output nutrients were N – 73.9–92.3%, P – 74.9–110.0%, K – 51.4–81.2%, respectively. Accumulation of nutrients in the yield was influenced by mineralization of incorporated organic manure. The highest amount of nitrogen in spring barley yield was accumulated during its cultivation after incorporated red clover biomass, meanwhile potassium – after white mustard. Straw, applied together with nitrogen (N_{45}) fertilizer or cover crop biomass also significantly increased nitrogen and potassium accumulation in cereal yield. During the year, less favourable for cover crop cultivation, the majority of nitrogen and potassium in spring barley yield was accumulated when mineral nitrogen (N_{45}) fertilizer was applied for initial cultivation of white mustard or mineralization of straw.

4. Red clover, mixture of white clover and Italian ryegrass and white mustard biomass cultivated in cover crop had a tendency to increase total nitrogen content in soil. More significant total nitrogen increase (1.4–5.7%, compared to the check treatment) was recorded after straw together with mineral nitrogen fertilizer or biomass of cover crops was applied for fertilization.

5. Straw (N_{45}), used for manuring increased mobile potassium content in the soil by on average 7.9%, compared to the treatment where straw was removed from the soil. Cover crop did not have any major effect on the change of potassium content in the soil. The effect of applied measures on mobile potassium variation in the soil was not substantial.

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Tarpinių pasėlių bei šiaudų, panaudotų trąšai, įtaka vasarinių miežių derliui ir dirvožemio agrocheminėms savybėms

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Santrauka

Lietuvos žemdirbystės instituto Joniškėlio bandymų stotyje sunkaus priemolio glėjiškame rudžemyje (RDg), *Gleyic Cambisol* (*CMg*), 2003–2006 m. atlikti tyrimai, siekiant nustatyti tarpinių pasėlių (*Trifolium pratense* L., *Trifolium repens* L., *Lolium multiflorum* Lamk., *Sinapis alba* L.) biomasės ir šiaudų, panaudotų trąšai, įtaką augalų derliui ir dirvožemio agrocheminėms savybėms. Nustatyta, kad per dvejus poveikio metus vasarinių miežių derliuje sukauptos bendrosios energijos kiekį iš esmės padidino tarpinių pasėlių augalai ir jų sąveika su šiaudais. Naudotos mineralinių trąšų vidutinės normos (N – 140, P – 26,2, K – 49,8 kg ha^{-1}) daugeliu atvejų lėmė neigiamą maisto medžiagų balansą. Tarpinių pasėlių augalai, vieni arba kartu su šiaudais panaudoti trąšai, ne visada užtikrino šiaudų mineralizacijai reikiamą kiekį azoto ir vasarinių miežių mitybą NPK. Judriojo kalio kitimui dirvožemyje daugiausia teigiamos įtakos turėjo šiaudų panaudojimas trąšai. Suminio azoto padidėjimo tendencija nustatyta trąšai panaudojus šiaudus su mineralinėmis azoto trąšomis arba tarpinių pasėlių biomase.

Reikšminiai žodžiai: tarpiniai pasėliai, šiaudai, javų derlius, NPK derlius, dirvožemio agrocheminės savybės.